Aquatic Nuisance Species Effects on Fisheries Sustainability

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What are Aquatic Nuisance Species?
Aquatic nuisance species (ANS) are non-native organisms that interfere with our current uses of the water or the economically important fisheries of the lake. Well known examples include sea lamprey (*Petromyzon marinus*) or the zebra mussel (*Dreissena polymorpha*). Over 160 non-native species have been introduced to the Great Lakes some have been intentionally introduced while others hitched a ride on ocean-going vessels or gained access to the upper lakes via connecting canals.

These non-native species have the potential to interact with native or desirable Great Lakes species in essentially one or more of three ways: predation, competition for resources and habitat modification. Predation can occur on the eggs, larvae, young and adult; competition can be for living space as well as forage. The predative and competitive interactions of ANS with native and desirable species can change with life stage. For example, white perch (*Morone americana*) larvae and juveniles compete for forage with the larvae or juveniles of native species. As adults white perch may prey on the larvae or juveniles of the same species. Zebra mussels (*Dreissena polymorpha*) modify the bottom (benthic) habitat as they form dense colonies on cobble substrate and can even cover open sand as the mussels form clumps and spread from nearby firm substrate.

ANS pathways
Aquatic nuisance species come to the Great Lakes in any of several pathways. Canals built to facilitate settlement and trade also allowed non-native species access to the Great Lakes basin. The Erie, Hudson, Welland and Chicago Sanitary and Ship Canal removed natural geographic barriers that historically protected the Great Lakes from many invaders. Ballast water used by present-day ships for safety when not carrying cargo, carried many non-native species from Europe across the Atlantic and into the Great Lakes.

Other non-native species were intentionally introduced or were introduced into adjacent lakes or streams and escaped into the Great Lakes via tributaries. Some of the intentional introductions like Pacific salmon have been beneficial, other such as common carp have had less desirable effects. Today we recognize the potential for other pathways to provide a means for non-native species to enter the Great Lakes. Live bait harvested from the wild can carry with it unwanted minnows or other fish species as well as fragments of invasive plants. Organisms released by well-meaning water gardeners can potentially become nuisances once they become established. Finally, the live fish trade is coming under increased scrutiny as a potential vector for the introduction of non-native species. Asian carp used on both aquaculture and sold as a live food fish are raising grave concerns as individuals are occasionally found in the Great Lakes and as the population in the Illinois River expands its range northward towards Lake Michigan.

<u>Canals</u>
There is no more economical method to move bulk goods than by water. (Get train and truck equivalents). Economic interests drive urban and infrastructure development. As our nation's population and need for materials increased, so too did the need to move people and goods efficiently. Following on the heels of settlers, Great Lakes invaders used the Erie and Welland canals to gain access to the upper lakes from the Atlantic Ocean. The Chicago Sanitary and Ship Canal provides an avenue for dispersal between the Great Lakes and the Mississippi River.

Examples of species that came to the Great Lakes via canals include the sea lamprey, white perch, alewife (*Alosa pseudoharengus*), three-spine stickleback (*Gasterosteus aculeatus*) and four-spine stickleback (*Gasterosteus spinulosus*).

The Erie Canal was completed in 1825 to facilitate westward settlement from the East coast. Each of these canals began as a small water-filled ditch plied by cargo-filled barges towed by mules. Expansion over the decades allowed the passage by vessels loaded with cargo and facilitated more rapid transportation of good and people. Each improvement of the canal system opened wider the aquatic access to the Great Lakes by Atlantic coast species.

The Welland Canal forms a by-pass around Niagara Falls, perhaps the significant geographic barrier that protected the Great Lakes from Atlantic Coast species. The Welland Canal was expanded to its present form in 1929. Prior to that ships had to unload cargo into smaller canal barges for passage through the canal. Expansion of the canal allowed larger ships to pass from Lake Ontario to Lake Erie without having to unload. This was a huge cost and labor savings but removed the protection offered by the falls.

Built in 1910, the Chicago Sanitary and Ship Canal (CSSC) cut through a low continental divide that once separated Lake Michigan from the Des Plaines River. This divide, barely more than 15 feet high formed the division between the Great Lakes and Mississippi River drainage basins. Until the mid 1970's water quality in the CSSC was very poor and formed an effective barrier to the spread of native as well as non-native species through the canal. Improvements in water quality after passage of the Clean Water Act in 1972 now allow many fish species, both native and introduced, to thrive in the canal system. The CSSC was one route through which the African zooplankton *Daphnia lumholtzi*, has gained access to the Great Lakes. This is also the route via which the zebra mussel and round goby passed from Lake Michigan to the Illinois River and beyond.

Attention is focused on the CSSC today as Asian carp are spreading from the Illinois River towards the canal and could potentially reach Lake Michigan. Presently an electric barrier is in place which may hinder or halt the spread of these fish to Lake Michigan. But the electric barrier does not stop all life stages of all species from passing up or downstream. Other improvements and barrier approaches need to be developed to attain a more permanent closure to the spread of invasive species via the CSSC.

<u>Ballast Water</u>

Ballast water, used by cargo vessels for stability had ferried European species from distant freshwater ports to the Great Lakes. When not carrying cargo, ships pump water into special ballast tanks along the sides, keel, bow and stern to keep the ship stable during the voyage. When the ships pumped on ballast water at a foreign port, they also inadvertently pumped on organisms. The water and entrained organisms were carried across the ocean and discharged into Great Lakes harbors when the ships arrived to carry cargo back to Europe.

In 1993, the U.S. Coast Guard required all ships entering the Great Lakes in a ballasted condition to perform an open ocean ballast exchange. Ships in a ballasted condition that are bound for the Great Lakes must stop in the open ocean and exchange their freshwater ballast for salt water ballast. The exchange must be performed in water greater than 2000 meters in depth and over 200 miles outside the United States exclusive economic zone. The exchange can take as much as three days to complete and requires calm seas. The exchanged water in the tanks must be 35 parts per thousand (ppt). The operation is not without hazard to the vessel and crew and it is the Captain's discretion as to the whether to perform the operation. If the vessel is not in compliance when it enters U.S. waters the U.S. Coast Guard will force the ship to exchange ballast in a secondary exchange zone or it will not be allowed to discharge ballast in the Great Lakes.

Only about 15 percent of the ships coming into the Great Lakes are in a ballasted condition, the other 85 percent are carrying cargo. Ships carrying cargo are said to have No Ballast On Board and are called NoBOBs. NoBOBs vessels are not required to exchange their ballast. These ships are however carrying some residual, unpumpable ballast water and mud in their ballast tanks. The volume of this water varies but can be several thousand gallons. Ship owners and many governmental agencies and researchers are working together to find ways to treat or handle ballast to keep it free of invasive organisms.

Most treatment or filtration methods are expensive and often difficult to retrofit onboard the vessels. The cost of the treatment system can exceed the value of older vessels causing ship owners to put the ships out of service. Some examples of ballast treatment options include filtration, ultraviolet light, deoxygenation, heat or chemicals; each approach has advantages and disadvantages. Another option is to better manage how and where the ship takes on ballast to avoid sediment, potentially bacterial laden sources and freshwater organisms.

Examples of organisms introduced in ballast water include the zebra mussel, round goby (*Neogobius melanostomus*), tubenose goby (*Proterorhinus marmoratus*), and Eurasian ruffe (*Gymnocephalus cernuus*), spiny waterflea (*Bythotrephes cederstroemi*), and the fishhook waterflea (*Cercopagis pengoi*).

<u>Stocking and Escapes</u>

Most species that have been stocked intentionally are not considered nuisance species, though there are exceptions. The common carp (*Cyprinus carpio*), for example was stocked in the early part of the 20^{th} century to provide a familiar food fish for European settlers (Becker 1983). Popularity of the fish did not expand as expected and the environmental effects as the fish feeds have been devastating.

Another familiar fish, the rainbow smelt (*Osmerus mordax*) escaped from Crystal Lake where it was stocked in Michigan. This diminutive fish has supported an economically important recreational and commercial fishery for over fifty years and today is relied upon as a portion of the Lake Michigan forage base.

Potential interactions

Invasive species interact with native species is through predation and competition. Non-native species prey on the eggs, larvae, juveniles and adults of our native species and compete with all these life stage for forage and living space. This interspecific competition affects the sustainability of the Great Lakes fisheries. Each new species introduced to the system requires food and living space in order to survive. Most invasive species are good competitors and may be able to displace or out-compete desirable species.

Forage Effects

For some interactions the impact is readily apparent, big fish feed on little fish and there's only so many little fish to go around. But other interactions are somewhat less obvious. Zebra mussels are filter feeders. This means they pump water over their gills and strain out the tiny animal and plant plankton. This is the food that young sport and commercial fish rely on once their yolk sac is absorbed and they begin to feed. If these young fish do not get enough to eat at this critical life stage they quickly starve to death.

The interaction between smelt and lake trout is similarly sinister. Smelt, a land-locked marine species has high concentrations of thiaminase in their body. Thiaminase is an enzyme that breaks down thiamine, an essential vitamin. Thiamine is abundant in the marine environment but is less so in the freshwater environment. When lake trout feed heavily on smelt, the thiaminase in the smelt reduces the concentration of thiamine in the lake trout. This does not perceptibly affect the adult lake trout but does affect the viability of the lake trout larvae. This effect was determined to be the cause of early life mortality syndrome (EMS) in lake trout. The effect does not occur in all lake trout that feed on smelt but it may be a contributor to the limited reproductive success of lake trout in Lake Michigan.

Invasive zooplankters like the fishhook waterflea compete with larval fish for food but can also prey directly on the larval fish. These large-bodied plankton invaders are les vulnerable to predation by larval fish and may cause fish to prey more heavily on the smaller native zooplankton.

Predation

Many Great Lakes invasive species feed directly on our native fishes. The destructive feeding habits of the lamprey are well known. Each lamprey can kill as much as 40 pounds of fish during the parasitic phase of its life cycle. Lampreys do not usually feed on their host until it is dead. They feed until they are full or the fish becomes debilitated then release prior to the death of the host. The host may be weakened by blood loss or succumb to infection of the wound. The fish that survive are left with unsightly scars.

Alewives are known predators on yellow perch larvae and may be a contributing factor in the low abundance of yellow perch in Lake Michigan though other species, both native and non-native prey on yellow perch as well. White perch (*Morone americana*) prey on native species as well as their eggs. Round gobies are voracious egg predators and will surround a bass nest, quickly darting in to gorge on the eggs if the guardian male is removed from the nest.

Habitat

Zebra mussels affect the habitat fish live in. As zebra mussels feed they remove plant plankton from the water, this in turn causes the water to become clearer. This has two effects. First it can make larval fish more susceptible to predation by making them easier for predators to see. Second, light can penetrate deeper into the water column. Fish that prefer darker water such as smelt and walleye may seek deeper water to evade the penetrating rays of the sun. As the smelt move to deeper water so too do their salmonid predators. Thus the clearing of the water by zebra mussels can affect the behavior and distribution of sport fish.

The other effect of zebra mussels is on the lake bottom (benthic) habitat. As zebra mussels colonize the cobble and other hard substrate on the lake bottom they can fill crevices and spaces between the rocks that formerly created feeding sites and shelter locations for small invertebrates, fish and fish eggs. The fouling and clogging of spawning substrate leaves eggs more vulnerable to predators.

Examples of Aquatic Nuisance Species

Sea Lamprey

Sea Lamprey entered the upper lakes in the 1920's via the Welland Canal. Though historically present in Lake Ontario, it is not clear whether they were native there or if they gained access to the lake via the Erie or Hudson canals. Lamprey expanded their range into Lake Michigan by 1936 and quickly began to eliminate the large native fishes including ciscoes, whitefish and lake trout. In Lake Michigan, as a result of sea lamprey predation and commercial harvest, lake trout were essentially eliminated by the mid 1950s.

The effect of sea lampreys is quite obvious; they are parasitic as adults feeding on nearly any large species of fish. Each adult lamprey can kill up to 40 pounds (18 Kg) of fish during its parasitic phase. Sea lampreys swim upstream to spawn, which is probably the main reason they originally entered the lakes. The sea lamprey control program has been underway for nearly 40 years using chemicals and barriers in their spawning streams. Despite success in many areas, populations of sea lampreys continue to exist in the Great Lakes and are expanding in some areas. Recent approaches to sea lamprey control include sterile male release and most recently researchers have synthesized attractant pheromones produced by male lamprey. This has the potential to concentrate spawning females and make control efforts more efficient.

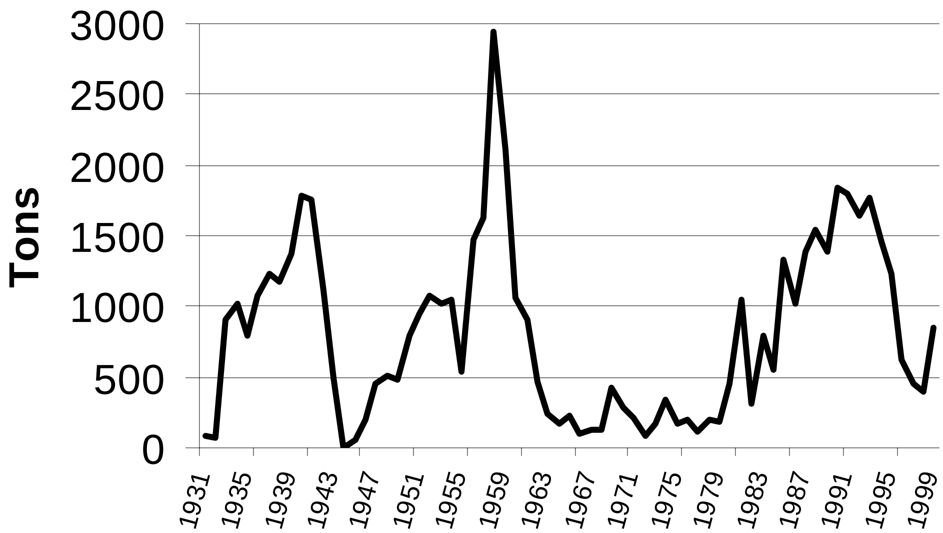
Of the upper Great Lakes, Lake Superior is the only one currently with a self-sustaining lake trout population. Lake trout in Lake Michigan and Lake Huron are maintained through stocking programs. The Great Lakes Fishery Commission coordinates the sea lamprey control efforts and the effort to reestablish self-sustaining lake trout populations.

Rainbow Smelt

Rainbow smelt are native to the Atlantic Coast, including a land-locked population in Maine. Efforts to establish rainbow smelt in Lake Michigan through egg stocking was unsuccessful. The current population in Lake Michigan is the result of adults that escaped from Crystal Lake in Michigan. Smelt were stocked into Crystal Lake in 1912, adults escaped over the Crystal Lake dam; smelt were first found in Lake Michigan in 1926.

Once established, the smelt population expanded rapidly in Lake Michigan becoming very abundant in the 1930's. The smelt was nearly eliminated from the lake in 1941 to 1942 by an unknown pathogen. However, by the mid 1950's and into the 1960's the fish were once again highly abundant.

The Lake Michigan smelt harvest has fluctuated widely over the last 60 years. This type of population expansion and decrease is typical of invasive populations. One factor in the population expansion of the smelt in the 1950's could be the lack of predation pressure as lake trout were essentially eliminated by sea lamprey. The smelt population declined again in the early to mid sixties, roughly coinciding with the stocking of Pacific salmon.



Smelt spend most of the year in deep water offshore. There, they feed on benthic invertebrates such as opossum shrimp and amphipods, but smelt also consume other small fish. In the spring, smelt move from deeper water offshore into shallow nearshore waters to spawn. The spawning season lasts for about two weeks in a given area, but the spawning season extends from March into May. The fish begin to move to the mouths of tributaries when the water reaches about 40^{o} F. The fish may swim some distance upstream to spawn or may spawn in shallow water over gravel deltas at stream mouths. Spawning generally occurs at night.

Rainbow smelt east zooplankton, small fish and benthic invertebrates, in this way compete with whitefish, ciscoes and young sport fish for food. Smelt provide forage for trout, salmon, walleye, perch, whitefish and other predatory species in the lake. However, smelt like alewives are high in thiaminase and do not provide as high a quality of forage as native fishes. Female lake trout that feed on smelt may produce eggs low in thiamine resulting in early mortality syndrome in the larvae.

Rainbow smelt spawning runs supported recreational fisheries for many years, but since the mid 1990s the numbers returning to shore have decreased. The exact cause of this decline is unknown. Some anglers attribute it to over-harvest by commercial trawlers. This is unlikely however because the population seems to have diminished throughout Lakes Huron and Michigan and commercial smelt trawling occurs only in a small area along the western shore of Lake Michigan and in Green Bay.

Alewives

Alewife (*Alosa pseudoharengus*), is an Atlantic Ocean native that also gained access to the upper lakes via the Welland Canal. Alewives are anadromous (swimming upstream to spawn) and, like sea lamprey continued their upstream migration and became land-locked in the Great Lakes. Alewives entered Lake Michigan in about 1949 at a highly opportune time, just as the populations of major predators in the lake had diminished to nearly non-existent levels. Without a controlling predator, alewife populations quickly expanded throughout the lake.

Alewives are a marine coast species, as such they are poorly adapted to rapid temperature changes and the physiological stresses associated with life in fresh water. These two factors combined with physical condition or age of the fish can result in spectacular spring alewife die offs as these fish congregate near shore and tributaries to spawn.

Alewives spend much of the time in the winter in deep waters of the lake where temperatures are cold, but fairly stable. In the spring the fish begin to move towards shore, gathering near tributaries. Unlike the marine environment which offers more stable near shore temperatures, springtime water temperatures in the near shore waters of the Great Lakes can vary dramatically over a 24-hour time period due to day and night variation, seiches and upwellings. These changes in temperature can subject the fish to thermal stress as they move away from deeper water where the thermal regime is more stable.

A second factor contributing to the alewife die off is the osmotic stress associated with life in fresh water. Freshwater fish tend to have larger kidneys than their saltwater counterparts. The bodies of fresh water fish are at a higher salt concentration than the surrounding water. As a consequence, fresh water fish must constantly pump water out of their bodies; they have evolved large kidneys to help them do this. Between the osmotic stresses, the temperature changes and the normal stresses of spawning, alewives can die off in astounding numbers in early June. These die-offs were particularly dramatic in the early 1960’s when alewife numbers were high.

Two actions were taken to try to reduce the alewife population and the nuisance created by the die offs. The first was to stock Pacific salmon as a new, open-water predator in the lake. The salmon replaced the nearly absent lake trout as the top-level predator. Mechanical removal of the over-abundant alewife occurred as commercial alewife trawling began in Wisconsin in 1981. This practice continued until 1994 when alewife abundance was deemed low enough to discontinue physical removal of the fish. Today, alewives are managed solely for the purpose as forage for pelagic species in the lake. Fish managers are not able to affect the alewife abundance except through manipulations of the number of salmon or steelhead trout stocked each year. Fish managers cannot control the weather or habitat affecting the annual spawning success of alewives; they must rely on natural reproduction to maintain the alewife forage base in the lake. Though the abundance of predators can be estimated, changes in spring weather patterns and temperature fluctuations result in variable alewife year class sizes. The US Geological Survey – Biological Resources Division monitors alewife abundance in the fall using acoustic sonar surveys.

Zebra Mussels & Quagga Mussels

Zebra mussels have direct effects on how people use Great Lakes waters but they may also be affecting behavior of Great Lakes fish and affect their foraging patterns. Zebra mussels are filter feeders. This means that as they pump water over their gills they strain tiny food particles (algae and zooplankton) from the water. An average-size zebra mussel can filter a liter of water a day. When you consider the sheer numbers of zebra mussels present in the lake (more than 1,000 /ft^2), you can imagine the volume of water filtered by these mollusks. It has been estimated that the zebra mussels in Lake Erie filter water equivalent to the entire volume of the lake every three days.

This has several effects. First, filter feeding competes directly with larval fish for food. The zebra mussels are eating the same food items (tiny zooplankton) that larval fish seek as their yolk sac is absorbed. Second, zebra mussels compete for food with the forage that very young fish need to consume. As zebra mussels consume algae, they compete for food with larger zooplankton. Finally a secondary effect of filter feeding is that the water gets clearer. In addition to making food less abundant and more difficult for larval fish to find, clearer water that results from filter feeding may also make larval fish more vulnerable to predation. So we see that zebra mussels compete with larval fish for food putting them at risk for survival and may make them more vulnerable to predation.

Zebra mussels also affect habitat for larger fish. As zebra mussels colonize rock and reef areas they can make these substrates less suitable for foraging, spawning and egg incubation. The sharp edged zebra mussel shells can abrade the mouth parts, fins and bodies of fish foraging among the mussel beds and rocks. As zebra mussels cover rocky substrate the rocks can become less suitable for nest building and for egg incubation. Lake trout select spawning sites that possess large cobble with deep interstitial spaces in which the eggs can settle and be protected from predation during their long incubation. Zebra mussels can clog these interstices, preventing the eggs from falling between the rocks leaving the eggs vulnerable to predation. Eggs that do fall between the rocks may suffer reduced oxygen levels as zebra mussels deposit feces and pseudofeces on the bottom.

The other way zebra mussels can affect habitat is by making the water clearer. As the water clears the light penetrates deeper into the water. Light sensitive fish will seek deeper, darker waters. If those fish are forage for a predator, the predator may move to deeper waters as well. Deeper light penetration may also be contributing to the growth of filamentous algae (*Cladophora*). The algae occur in waters at least 90 feet in depth and fouls fishing nets. The same algae washes up along shorelines through the summer months forming noxious smelling anoxic masses.

White Perch

White perch (*Morone americana*), native to the Atlantic coast likely entered the Great Lakes through the Hudson and Welland Canals. White perch is not a perch at all, but rather is in the temperate bass family. It is in the same genus and closely resembles yellow bass, white bass and striped bass. White perch have been mistakenly stocked with white bass in lakes outside the Great Lakes basin which has facilitated it spread into the Ohio River basin.

White perch forage preferences overlap with yellow perch, walleye, smallmouth bass and the young of many of our popular sport fish stocked in the Great Lakes. White perch will eagerly consume eggs and young of desirable native sport species. White perch themselves are a popular sport species on the East coast and have the potential to be a desirable sport species in the Great Lakes. White perch is harvested commercially in Lake Erie and is abundant enough for commercial harvest in Green Bay, though historically PCB contamination has historically been a concern there.

<u>Round Gobies & Tubenose Gobies</u>

The round goby (*Neogobius melanostomus*) and tubenose goby (*Neogobius proterorhinus*), native to the Caspian Sea region of Europe, were brought to the United States in the ballast water of ocean going vessels. Round gobies were first discovered in the Great Lakes in 1988 in Lake St. Claire. Today they are present in parts of all the Great Lakes and have spread to the Mississippi River basin, nearly to the Illinois River through the Chicago Sanitary and Ship Canal.

These small bottom-dwelling fish prey on eggs of desirable sport fish in near shore waters of the Great Lakes. Gobies also consume benthic (bottom dwelling) invertebrates including scuds, insect nymphs and larvae and zebra mussels. Round gobies consume zebra mussels between 4 to 11 mm in length. They cannot physically swallow the very large ones and may not be able to dislodge the very small zebra mussels from cracks and interstices. So while gobies may help reduce the number of zebra mussels within localized areas, they do not control the population overall.

Gobies are a concern because, like other invasive species they compete with our native fish for forage and habitat and consume eggs of desirable sport and commercial species. Non-native gobies dislodge native sculpins from desirable habitat causing the sculpins to be more vulnerable to predators and to use less favorable spawning habitat. Anglers find gobies a nuisance too. Gobies can become quite abundant locally, are proficient bait stealers and often turn up as an unintended catch for anglers.

In North America gobies mature at about two years of age and can spawn up to six times through the course of the summer. This rapid population growth can cause problems for fish that spawn on or build nests in the rocky, cobble areas preferred by the goby. Walleyes, lake trout, smallmouth bass and other sunfish lay eggs on cobble or build nests in gravel areas. Through their voracious tendencies and abundance gobies can quickly consume unprotected eggs laid on cobble. Though male smallmouth bass protect their nests, gobies will quickly swarm a nest and consume the eggs if he is removed from the nest even temporarily by an angler.

To help prevent their spread do not use gobies as bait anywhere outside the Great Lakes. When you purchase bait take a moment to ensure that you got the minnows you paid for and not some additional unwanted exotic species that could spread if released.

<u>Eurasian Ruffe</u>

The native range of the ruffe (pronounced rough) includes northeastern France, England, the rivers entering the Baltic and White Seas, most of Siberia, and the Baltic Sea. Its spiny and slimy characteristics make it unsuitable as a forage and bait fish and it has little or no commercial value. The ruffe probably came to the United States in the ballast water of ocean-going vessels. First found in western Lake Superior in 1986, it has spread along the southern shore of Lake Superior and has been found in Thunder Bay in Lake Huron, in Thunder Bay, Ontario on the northern shore of Lake Superior and in Escanaba in Lake Michigan.

Ruffe are fast growing, maturing in about two or three years and have a high reproductive capability. Ruffe spawn between mid-April and July depending on water temperature. Females tend to live longer than males, with an average life span of seven years; males live from three to five years. Ruffe grow rapidly and can begin to reproduce at one to two years of age. Females produce up to 200,000 eggs per season allowing rapid population growth.

Like other invasive species it tolerates a wide range of environmental conditions. In its native range the ruffe is found in fresh to brackish waters with salinity up to 5 ppm. Ruffe prefer lakes or slow moving rivers with soft bottoms. Ruffe do well in turbid waters but are found in deep, clear lakes too.

It is likely to compete for food with other perch species (walleye and perch) as well as other fish that live and feed on soft-bodied invertebrates that live in or on the bottom. Though ruffe have poor eyesight they can feed in total darkness using sensory organs called neuromasts. These organs are located in canals in the head of the ruffe and can detect minute water currents as might be caused by the movement of gills on the abdomen of a mayfly.

The most likely means of spread for this invasive fish is range expansion and through inadvertent introductions through ballast water and potentially bait. It is possible that the Lake Huron and Lake Michigan populations are new introductions and were not spread from Lake Superior. It could also be mixed with wild-harvested minnows used or sold as bait.

The ruffe has the potential to disrupt the Great Lakes fisheries through competition for food with young and adults of native species. Ruffe have the potential for rapid population growth. A large, new population of ruffe a Great Lakes ecosystem could mean less food and space for other fish with similar diets and feeding habits. Young ruffe will compete with young perch, walleye and other zooplankton-eating fish. Adult ruffe will compete with yellow perch and other fish that eat soft-bodied, bottom dwelling invertebrates. Ruffe currently comprise as much as 80 percent of the biomass in the shallow waters of western Lake Superior. Their abundance suggests they would have an immediate impact, yet that may not be the case. Models suggest it may take as much as 25 years to for the impact of ruffe on the Lake Superior to be measurable.

Chemical control to reduce the ruffe population was considered as an option soon after ruffe were found in the Great Lakes. Ruffe are susceptible to TFM, the same chemical agent used to control lampreys. This option was later abandoned as being too expensive and as having a low likelihood of long-term success. Without population control ruffe will likely continue to expand their range along the southern shore of Lake Superior. Another significant effort to slow the spread of ruffe involves Great Lakes vessels that operate in the Duluth-Superior harbor. Operators of these vessels have agreed to draw ballast water from deep areas of the lake or to draw water using intakes on the side rather than near the keel of the ship. These actions are intended to reduce the likelihood of transporting ruffe to other parts of the Great Lakes through inter-lake commerce.

In Minnesota and Wisconsin it is illegal to possess or transport a live ruffe. Ruffe cannot be used as bait by anglers, and bait dealers who trap in areas infested with ruffe should take special precautions to insure they are not contributing to the spread of this exotic species.

Spiny Waterfleas

Waterfleas is a common name for the small animal plankton that occurs in the water column. Native waterfleas such as Daphnia comprise the first food for the larvae and young many of desirable sport species. Invasive waterfleas are problematic because the have long spines or short, stout spines that protect them from predation. These non-native plankton species prey on our native animal plankton and thus compete for food with our native fishes. So these tiny invaders are less vulnerable to our young native fish and compete with them for food. By being less vulnerable to predation they may cause predation to shift disproportionately to native zooplankton. The spines themselves are indigestible for small fish; these young fish may be unable to feed as their gut is full of undigested spines.

There are three species of spiny zooplankton found in the Great Lakes: fishhook waterflea (*Cercopagus pengoi*), spiny waterflea (*Bythotrephes cederstroemi*) and an African waterflea (*Daphnia lumholtzi*). The fishhook waterflea and the spiny waterflea were introduced to the Great Lakes in ballast water. They are both native to the Black and Caspian Sea region of Europe. The African waterflea was introduced with Nile perch in Texas and spread north via the Mississippi River to the Illinois River up to the mouth of the Calumet River near Chicago. *Daphnia lumholtzi* has also been found in Lake Erie, but has not been located between the two sites.

Both the spiny waterflea and the fishhook waterflea are known to foul trolling lines and downriggers in the Great Lakes. Not only is this a nuisance for anglers because it makes it difficult to reel in fish, but it may also provide a means for these waterfleas to spread. The fishhook waterflea produces a special type of egg called a resting egg. The resting egg is highly resistant to drying, so even if the female dies and dries up on the fishing line, the eggs may still be viable. If transported to another lake on the fishing gear the resting eggs could start a new colony. The offspring from resting eggs of fishhook waterfleas are able to reproduce without males so they could create a new population once hatched in the new lake.

Spiny waterfleas may affect the survival of newly hatched, economically important fish species and so may directly affect naturally reproducing fish such as whitefish, chubs, yellow perch, walleye, smelt, and some of the trout. However many minnow species, which are forage for larger species, prey on zooplankton and so may be adversely affected by the presence of spiny waterfleas in their diets. Adult smelt and alewives are able to crush the spines of the spiny waterflea and fishhook waterflea and so are able to prey upon these species.

Effects of Invasive Species

Invasive species affect our native and desirable introduced species in several ways – competition for food and shelter, modification of habitat, direct predation and parasitism. The consequence of these interactions is a shift in biomass from desirable, economically important species to species that may be neither desirable nor exploitable. Though the total mass of living tissue may remain relatively constant there will be more lampreys or zebra mussels or gobies or sticklebacks instead of lake trout or whitefish. Rarely does an invasive species fill an “empty” ecological niche or exploit a new resource within an ecosystem. Each new species added to the system takes away forage or habitat from another. This may extend to the point or elimination of the original species but most often will result in the reduction of the abundance or physical condition of the original species.

Generally for us, users of the Great Lakes resources, the greatest problem with invasive species is that they adversely affect the ways in which we use the ecosystem. We rely on stable ecosystems for recreational and commercial uses. Invasive species cause rapid and often undesirable changes in the features of the ecosystem we come to rely on for our own exploitation. Often we may be unaware of subtle ecosystem changes caused by invasive species. It is not until these alterations of food webs, recruitment and behavior affect the ways we use the natural resources of the lake do we become aware of or concerned about the invaders themselves or their effects. The effects we observe are fewer fish caught, the fish we catch are thinner or not the species we were after.

Correcting or reversing these effects is often physically impossible and at best costly. The cost for eliminating the northern snakehead fish from a small 11-acre pond was $110,000. Sea lamprey have been in the Great Lakes for over 50 years. Annual costs associated with their control are about $15,000,000 and they are still not eliminated from our lakes. The annual cost of coping with the effects of zebra mussels on Great Lakes municipal water facilities is over $50 million dollars. These control costs directly affect Great Lakes residents.

Summary

Invasive species affect our native and desirable introduced species in several ways – competition for food and shelter, modification of habitat, direct predation and parasitism. Generally the greatest problem with invasive species is that they adversely affect the ways in which we use the ecosystem. We rely on stable ecosystems for recreational and commercial uses. Invasive species cause rapid and often undesirable changes in the features of the ecosystem we come to rely on for our own exploitation. Often we may be unaware of subtle ecosystem changes caused by invasive species. It is not until these alterations of food webs, recruitment and behavior affect the ways we use the natural resources of the lake do we become aware of or concerned about the invaders themselves or their effects.

Correcting or reversing these effects is often impossible and at best costly. Sea lamprey have been in the Great Lakes for over 50 years. In 1998 the Great Lakes Fishery Commission received nearly $15,000,000 for sea lamprey control. Despite these efforts and expenditures sea lamprey have not been eliminated from our lakes. The annual cost of coping with the effects of zebra mussels nationally is estimated to be about $30 million dollars. Changes in the fisheries and how we use them affect us today and for generations well into the future. We must learn to use or deal with invasive species already present in the Great Lakes, but the most effective way to deal with them is through prevention of the introduction in the first place.

We must find ways to treat ballast water to prevent the transfer and introduction of invasive species into the Great Lakes while maintaining the economies associated with Great lakes ports. At the same time we must look to our inland transportation routes and trade to prevent the spread of fish from the live food trade into the Great Lakes. Finally Great Lakes recreational boaters, anglers those who harvest bait from the tributaries must take care not to spread invasive species in the Great Lakes to inland waters.

Make it a habit to drain water from the live well, bait well, motor and bilge areas of your boat before you leave the ramp at the end of the day. Clean weeds of the trailer, motor, anchor or other areas where they may become tangled. Dispose of live bait in the trash – do not release it into the water. Finally, wash your boat with hot water (105^{o}F) or let it dry for five days before going to another water body.

Prevention is the key to preserving our resources for generations to come. Share your knowledge with others and help them take the necessary steps so we can preserve our Great Lakes future together.

Additional Resources
For more information about invasive species visit your state Sea Grant web site or any of the following websites:
www.sgnis.org
www.anstaskforce.gov
http://nas.er.usgs.gov
www.glc.org/ans/anspanel.html
www.great-lakes.net
www.invasivespecies.gov